Procedural Volumetric Cloud Modeling, Animation, and Real-time Techniques, part 1

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Overview

- *Proceduralism*
- *Background*
- *Modeling Gases*

Overview

- *Cloud Modeling*
- *Examples Using Commercial Systems*
- *Hardware Issues and Real-Time Gases*
- *Conclusion*
- *Future Directions for Research*

Proceduralism: Advantages of Procedural Techniques

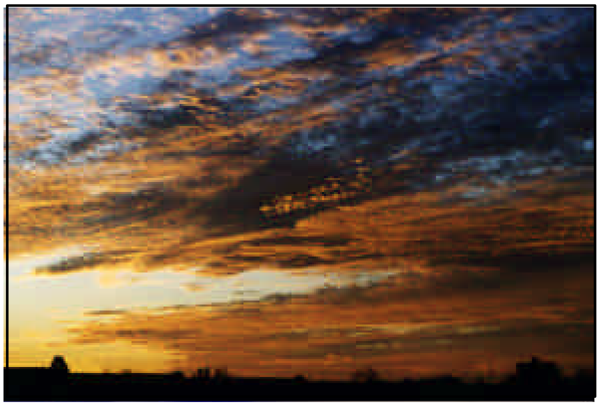
- *Flexibility*
- *Parametric Control*
- *Data Amplification*
- *Procedural Abstraction - High Level Control*
- *Complexity on Demand*
  - Inherently multi-resolution model
  - Computational savings
  - Ease of anti-aliasing

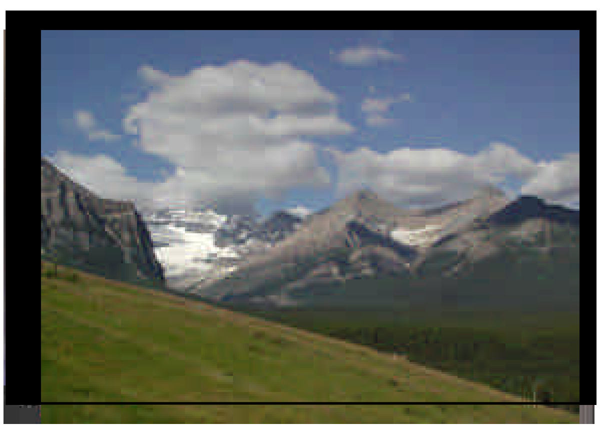
Background

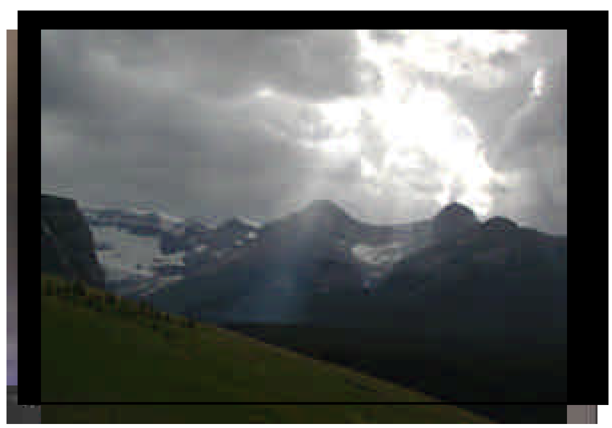
- *Why Model Gases ?*
- *Important Visual Characteristics*
- *Rendering System Considerations*

Why Model Gases ?

- *Visual Realism*
- *Artistic Effects*







Important Visual Characteristics

- *Amorphous*
- *Swirling*
- *Attenuation of Light*
- *Shadowing*
- *Illumination*

Example: Fog

Rendering System Considerations:

Issues	My System
Volume Rendering Support	*Scanline A-buffer w/ Volume Tracing*
Illumination Issues • Participating media - scatters, reflects, absorbs light • Low-albedo models (single scattering) • High-albedo models (multiple scattering)	*Low-albedo Illumination Model*
Volume Shadowing	*3D Table-based Shadowing* • Fast, efficient • 10 to 15 times faster than ray-traced shadows
Modeling Capability	*Procedural Volume Density Functions*

Modeling Gases: Previous Approaches

Surface Approaches
- Hollow/flat objects
- Interaction problems
- Fast

Volume Approaches
- Greater realism, flexibility
- Slower

Volumetric Modeling Advantages

Accurate Shadowing

Realistic Illumination

Realistic Simulation of Natural Volumetric Phenomena (Clouds, Gases, Water, Fire)

Volumetric Procedural Modeling (VPM)

Basic VPM Primitives
- Any function of three-dimensions
- Stochastic:
  - *Noise, turbulence, fBm*
- Regular: implicit functions
  - *Smooth blending*
  - *Useful primitives (spheres, cylinders, ellipsoids, skeletons)*

Volumetric Procedural Gas Modeling

Turbulence-based Procedures
- Perlin's noise and turbulence functions

Shape Resulting Gas
- Simple mathematical functions

Defines Volume Density

Basic Gas Procedure

Density =

*(turbulence(pnt)*density_scaling)^{exponent}*

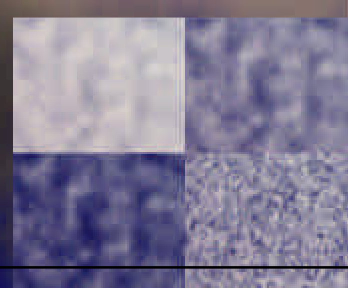
- Exponent typically 1.0 to 10.0

Gas Shaping Primitives

Power Function

Sine Function

Exponential Function



Steam Rising From a Teacup

Volume of Gas Over the Teacup

Basic Gas Procedure Used for Density

Steam Rising ...

Shape Gas Spherically

Shape Gas Vertically

Procedural Gas Animation

General Animation Approach

- Map screen space point to object space
- Move through gas space over time
- Evaluate density procedure
- Path direction produces opposite movement
- Path specified by
  - *Helical paths*
  - *Combination of primitive flow field functions*

Helical Paths

General Direction of Motion with Some Variation

Example of Downward Helical Path

- θ based on the frame number
- $x = \sin(\theta) * radius1$
- $z = \cos(\theta) * radius2$
- $y = -(down\_velocity * frame\_number)$

Helical Path Effects

Steam Rising

- Downward helical path

Fog Rolling In

- Horizontal helical path

Combination of Simple Flow Simulations

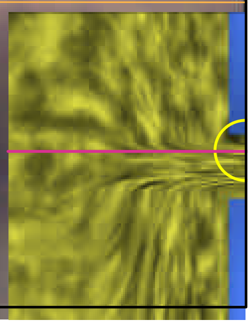
- *Wind Effects*
- *Flow Into an Opening*

Wind Effects - Gentle Breeze

- *Helical Path (for upward swirling)*
- *Spherical Attractor:*
  - Strength increases over time
  - Moves volume of steam

Flow Into An Opening

- *Motion Created by*
  - Angle limited spherical attractor
  - Angle limited spherical repulsor
  - Linear attractor
- *Also Works for Hypertextures*



Volumetric Cloud Modeling: Volumetric Procedural Implicits

- *Previous Volumetric Procedural Implicit Modeling*
  - Perlin: hypertextures
  - Stam: fire modeling, clouds
  - Kisacikoglu: gas plasma - Sphere
- *Previous Cloud Modeling*
  - Surface-based (Gardner)
  - Fractal-based (Voss)
  - Volume-based (Kajiya, Stam)

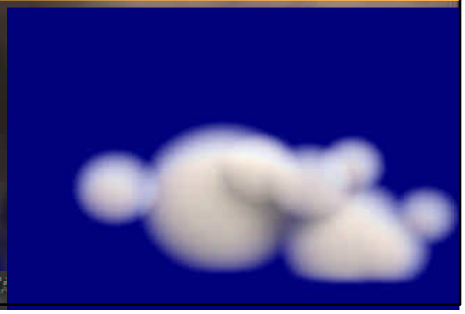
Volumetric Procedural Implicit Modeling

- *Two Tiered Approach*
  - Cloud macrostructure
    - *Volumetrically rendered implicit primitives*
  - Cloud microstructure
    - *Procedurally defined natural detail*
    - *Procedural volumetric density functions*

Cloud Macrostructure

- *Primitive-Based Implicit Models*
  - Currently: spheres, cylinders, ellipsoids
  - Wyvill's blending function
- *Ease of Specification, Animation, Global Deformation*
  - Easily controlled by particle system dynamics

Example Implicit Cloud



Cloud Microstructure

Volumetric Procedural Model

Built-in Multiresolution Model

Features:

- Main primitives: noise and turbulence
- Mathematical functions for shaping
- Natural controls

Simple Volumetric Procedural Model (VPM)

vpm(pnt)

- pnt = map pnt to procedural turbulence space
- turb = turbulence (pnt)
- density = pow(denseness*turb, wispiness)
- return(density)

Combined Model

Use Procedural Techniques to Perturb Sample Point

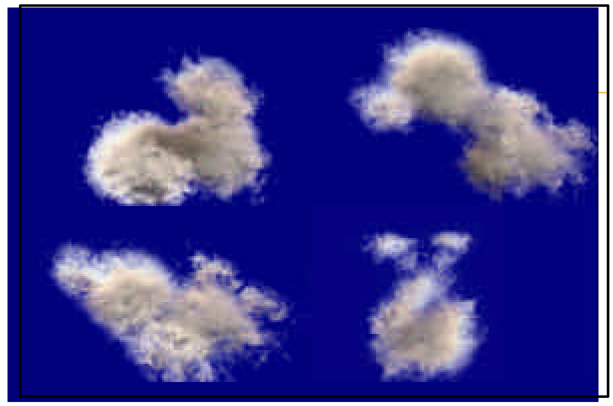
Calculate Implicit Density for Point

Calculate Procedural Density for Point

Blend These Densities

- blend = blend% * imp_density + (1-blend%)*proc_density*imp_density

Shape With Math Functions



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